FINAL REPORT

DETERMINATION OF THE EFFECTS OF HOT AND COLD WATER WASHING AND DRYING ON SHELF LIFE OF FRESH SASKATOON BERRIES

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Determination of the Effects of Hot and Cold Water Washing and Drying on Shelf Life of Fresh Saskatoon Berries

Project # 98000145

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A) Summary

The project objectives were to develop a pilot-scale operation for primary processing of saskatoon fruit and to examine the effects of hot and cold water washing on the shelf life of fresh saskatoon fruit. A pilot-scale line was assembled at the Saskatchewan Food Industry Development Centre and the operation was demonstrated to a group of fruit processors. Fruit quality characteristics were not compromised by washing. In 1999, the results indicated hot water washing delayed deterioration by reducing yeast and mold populations. In 2000, the hot water washing did not significantly reduce microbial populations. Hot water washing may improve saskatoon shelf life under conditions where excessive microbial growth is anticipated. A video of the pilot-scale operation was produced and distributed to industry.

B) Technical Report

1) Background & Objectives

The project's objectives were: (1) to develop a pilot-scale operation for washing and drying of fresh saskatoon fruit in accordance with recommended food safety guidelines for fresh produce processing; (2) to examine the effects of hot and cold water washing treatments followed by drying on the shelf-life of fresh saskatoon fruit; and (3) to determine the optimum time-temperature combinations for the wash/dry unit for fresh-pack saskatoon fruit.

Optimized post-harvest processing techniques for fresh saskatoon fruit are crucial to marketing fresh fruit, improving the quality of value-added products, and more importantly to safe human consumption. According to the food safety guidelines for fresh produce processing, fruit intended for human consumption should follow these steps after harvest: (a) sorting; (b) washing; (c) drying; and (d) packaging and storage (Garrett and McInerney, 1997).

Traditionally in Saskatchewan, the washing and drying steps are eliminated. Harvested fruit are packaged and frozen after sorting. Washing of the fruit is necessary to remove dirt, dust, and chemical residues, whereas the drying step plays an important role in removing surface moisture which could increase fruit susceptibility to microbial contamination. With increasing consumption of fresh saskatoon fruit, and the potential of a growing export market, it is necessary to establish industry-acceptable procedures for the post-harvest processing of fresh produce to ensure a safe food product.

Various methods are available for washing fruit. A recent innovation in this area originates from Israel (Fallik, 1998). In this method, fresh produce is exposed to a brief hot water wash (50-75 °C for 5-30 s) followed by a cold water wash. Fallik's (1998) method has been shown to have excellent potential for disinfecting and cleaning fresh produce, but most importantly it significantly increases the shelf-life of fresh produce. Epicuticular waxes of the produce appear to play a vital role in preventing dessication and acting as a barrier against infection after the hot water treatment. Research conducted by Knowles et al.(1996) on the epicuticular waxes of saskatoon fruit indicates close similarities to other fruits and vegetables,

suggesting that these waxes may play a similar role in saskatoon fruit under the same conditions. With respect to drying, Donahue et al. (1998) described a method which was effective in removing field water from the surface of freshly-harvested blueberries. These authors indicated that fans blowing over the fruit at medium speed did not have any adverse effects on the quality of fresh-pack blueberries.

Results from this project will be of direct benefit to Saskatchewan's agri-food industry. Consistent, high-quality products are necessary for success in today's marketplace. This project has the potential to contribute to the fruit industry's knowledge and skill of post-harvest handling of fruit thus helping to increase the quality of fresh and processed fruit products produced, and therefore improving the ability of both growers and processors to compete in the available markets. This project will help the developing native fruit industry, thus enhancing diversification of Saskatchewan's agri-food industry, and encouraging Saskatchewan farmers and rural residents to create economic opportunities and jobs. The project is integrated with the Saskatchewan Fruit Growers Association's Strategic Plan and with the Post-harvest Physiology of Fruit and Vegetables Program at the University of Saskatchewan. It is anticipated that commercial application of the results of this project will begin to occur with a year of project completion.

2) Activities & Achievements

Harvesting and Processing of Fruit

In the 1999 and 2000 seasons, saskatoon fruit of the cultivar Smoky were harvested from University of Saskatchewan plots in Saskatoon, SK. Fruit were collected with a hand-held harvester (BEI, South Haven, MI). The hand-held harvester vibrated as it was raked along the tree branches causing fruit to fall into catch frames. From the catch frames, fruit were put into ventilated plastic trays (Thunderbird Plastics, Burnaby, BC) and placed in a field cooler. The containers were placed directly on a layer of reusable ice substitute (Cyropak Corp., Vancouver, BC) that laid on each shelf of the field cooler. The cooler was a plywood shell lined with styrofoam insulation. Fruit were stored in the field cooler for approximately 30 minutes during transport, then fruit were stored at 4°C for up to 4 hours prior to processing.

The pilot-scale processing line consisted of an air draft cleaner and sorter (Hometown Machinery, Sundre, AB) and a washing/drying conveyor unit (BEI Inc., South Haven, MI) (Figure 1). This operation was set up in the Saskatchewan Food Industry Development Centre Inc. (Food Centre), Saskatoon, SK. Thermocouples were positioned throughout the washing/drying conveyor unit to monitor water and air temperatures (Figure 2).

Harvested fruit were deposited on the conveyor of the air draft cleaner (Figure 3). Fruit exited the air draft cleaner on to a sorting table, where the immature and diseased fruit were manually removed (Figure 4). Cleaned fruit were conveyed from the sorting table onto the washing/drying conveyor unit (Figure 5). Manual assistance was required to convey the fruit on to the washing/drying conveyor unit due to the greater width of the sorting table compared to the washing/drying conveyor unit. Fruit passed through the spray hood and under the blower of the

washing/drying conveyor unit, then were collected in a large plastic container (Figures 6 and 7). Temperature of the water spray inside the wash hood was set at 16°C in 1999 and 19°C in 2000 for the cold water wash or at 60°C hot water wash (in both 1999 and 2000), and the cool rinse remained set at 16°C in 1999 and 19°C in 2000 (Figure 2). Temperature was recorded every 20 s using a datalogger (Model DT100 Datataker, Data Electronics, Victoria, Australia). Four replicate processing runs at each wash temperature were performed (Table 1). All equipment was cleaned and sanitized after each processing run (Figure 8).

Control samples of fruit were taken from each run after manual sorting but prior to the fruits' entry into the washing/drying conveyor unit. Control and washed samples were packaged in heat-sealed plastic bags and stored at 0°C. In 1999, the plastic bags contained 600 g of fruit and the bags were opened and resealed on each sampling day. In 2000, a separate plastic bag containing 200 g of fruit was used for each sampling day. Thus, once a bag had been opened and sampled it was disposed of, unlike in 1999 when bags were resealed and used for subsequent sampling days.

Fruit Quality Analyses

Quality of the fruit was tested on the day of processing as well as seven, fourteen, and twenty-one days after processing. On the day of processing, duplicate control samples of fruit were taken from each run after manual sorting but prior to the fruits' entry into the washing/drying conveyor unit. Duplicate samples of processed fruit were taken from each run once the fruit passed through the washing/drying conveyor unit. Duplicate control and processed fruit samples were taken from bags stored at 0°C after seven, fourteen, and twenty-one days of storage. The schedule of sampling for quality testing is outlined in Table 2. Quality analyses were conducted only in 1999.

Quality tests performed included pH, soluble solids, colour, and texture. Juice extracts for pH, soluble solids, and colour analyses were obtained by manually macerating 50 g of fruit and decanting the liquid portion. The pH was measured with a Model 420A benchtop pH meter (Orion Research Inc., Boston, MA). Soluble solids content was determined by refractometer (Fisher Scientific, Nepean, ON) as per AOAC method 932.12 (AOAC, 1995). The colour of 7.5 g of juice extract contained in a petri-dish (60 mm diameter) was measured with a Miniscan XE colourimeter (Hunter Assoc., Reston, VA).

Texture analysis was performed by compressing ten fruit of uniform size and shape with a 10 cm-diameter compression plate (Figure 9). The compression plate was attached to a TA.XT2 texture analyzer (Texture Technologies Corp., Scarsdale, NY) which was equipped with a 25-kg load cell (Figure 9). Fruit were placed on a circular metal platform (6.5 cm in diameter) with the calyx end facing the compression plate and in a circular pattern approximately 1 cm apart and approximately 1 cm from the edge of the platform. The crosshead speed of the compression plate during analysis was 2.0 mm/s and the fruit were compressed to a depth of 7.5 mm (~ ¾ of the height of the fruit). The maximum force required to compress ten fruit was used as an index of firmness.

Statistical analysis was performed using the Proc GLM (General Linear Model procedure) from the Statistical Analysis Software (Sas Version 6.11 (SAS Institute, Gary, NY)). Duncan's multiple range test was used to determine treatment differences.

Microbial Analyses

Fruit microbial loads were evaluated on the day of processing as well as seven, fourteen, and twenty-one days after processing. On the day of processing, duplicate control samples of fruit were taken from each run after manual sorting but prior to the fruits' entry into the washing/drying conveyor unit. Duplicate samples of processed fruit were taken from each run once the fruit passed through the washing/drying conveyor unit. Duplicate control and processed fruit samples were taken from bags stored at 0°C after seven, fourteen, and twenty-one days of storage. The schedule of sampling for quality testing is outlined in Table 2. Total aerobic, as well as yeast and mold, populations were counted in 1999. Only yeast and mold populations were enumerated in 2000.

Each sample consisted of ten fruit which were aseptically collected in sterile bottles. Samples were combined with 100 ml 0.1% peptone water and shaken manually in a 90° arc 25 times. The resulting sample rinse was serial diluted (10^{-1} to 10^{-5}) with 0.1% peptone water and plated according to AOAC method 990.12 (Section E) for aerobic counts and AOAC method 997.02 (Section E) for yeast and mold counts (AOAC, 1995) (Figure 10).

Duplicate samples of the cool rinse water were aseptically collected during each processing run. These samples were serial diluted (10^{-1} to 10^{-3}) with 0.1% peptone water then plated according to AOAC method 990.12 (Section E) for aerobic counts and AOAC method 997.02 (Section E) for yeast and mold counts (AOAC, 1995).

Statistical analysis was performed using the Proc GLM (General Linear Model procedure) from the Statistical Analysis Software (Sas Version 6.11 (SAS Institute, Gary, NY)). The PDIFF option was used to determine significant differences among treatments and storage days.

3) Results, Discussion & Conclusions

Processing of Fruit

The pilot-scale processing line was well suited to this study. The air draft cleaner removed all leaf and twig debris, as well as some immature fruits, from the harvested saskatoon fruit. Manual sorting was required to removed diseased, immature, and overripe fruit.

A more efficient processing line would have been possible if a variable speed motor existed on the sorting table. The one speed motor available was too rapid to be in sync with the conveyor of the washing/drying conveyor unit. The widths of the conveyors of the sorting table and washing/drying conveyor unit were also incompatible. Minor equipment modifications to

channel the fruit exiting the sorting table on to the washing/drying conveyor unit were unsuccessful. Thus, increased manual handling of the fruit was required to move the fruit from conveyor to conveyor. The increased human contact with the fruit was undesirable, as it may have elevated the risk of contamination.

The spray hood and blower of the washing/drying conveyor unit effectively cleansed and dried the fruit. The blower which dried the fruit was not effective in drying the conveyor belt. The moisture remaining on the belt was deposited in the fruit collection container as it moved around the end of the conveyor. Reducing the amount of moisture adhering to the conveyor belt would be necessary in a industrial setting where a greater volume of fruit would be processed.

Figures 11 and 12 show the temperature profiles of the cold and hot water washing lines from 1999 and 2000, respectively. Each line represents the mean of four replicates. The layout of thermocouples for wash/dry line (Figure 2) corresponds to the legend on the Figures 11 and 12. Figures 11 and 12 indicate that water temperature was relatively constant for the duration of the experiments in 1999 and 2000, respectively. For the cold water wash, the cold water rinse and spray hood water temperatures were 16°C in 1999 and 19°C in 2000, which were the lowest water temperatures attainable under the conditions. Hot water temperatures were steady at 60°C in both 1999 and 2000. Ambient temperatures ranged from 25-29°C.

Optimum-time temperature combinations for processing were not determined. The equipment limitations, particularly the lack of conveyor speeds available, impeded altering the processing times. Because colder water temperatures were not attainable, the desired range of temperatures were not available. Therefore, determining optimum time-temperature regimes was not possible, given the facilities available.

Fruit Quality

Quality of the fruit was assessed in 1999. Samples of fruit subjected to the hot and cold water washes, as well as the fruit control (no washing treatment) samples were stored at 0°C for up to 21 days in heat-sealed plastic bags. Soluble solids, pH, colour and texture were monitored.

Figure 13 shows changes in pH during storage for the control, hot, and cold water washing treatments. Results of the analysis of variance are also shown below.

Source of Variation	Degrees of Freedom, df	Sum of Squares, SS	Mean Square, MS	F Value	Pr > F (5%)
Treatment, T	2	0.03	0.02	3.15	0.05
Storage time, S	3	2.23	0.74	144.05	0.0001
T x S	6	0.13	0.02	4.28	0.001
Error	100	0.52	0.01		

Treatments were significant, storage time was highly significant and the two-way interaction between treatments and storage time was significant. With respect to storage time, fruit pH increased from 0 to 21 days. At the present time, it is not clear why this increase occurred.

Changes in soluble solids during storage are shown in Figure 14. The analysis of variance results are shown below.

Source of Variation	Degrees of Freedom, df	Sum of Squares, SS	Mean Square, MS	F Value	Pr > F (5%)
Treatment, T	2	30.00	15.00	18.35	0.0001
Storage time, S	3	3.08	1.03	1.26	0.2935
T x S	6	1.49	0.25	0.30	0.9340
Error	100	81.75	0.82		

Treatments were highly significant, with the hot water treatment having higher soluble solids values than the control and cold water treatment. Storage time, and the two-way interaction between treatments and storage time were not significant.

Figure 15 illustrates the effect of treatments and storage time on Hunter L value. The analysis of variance table is shown below.

Source of Variation	Degrees of Freedom, df	Sum of Squares, SS	Mean Square, MS	F Value	Pr > F (5%)
Treatment, T	2	174.23	87.12	10.67	0.0001
Storage time, S	3	495.33	165.11	20.22	0.0001
T x S	6	108.16	18.03	2.21	0.05
Error	100	816.77	8.17		

Treatments, storage time and the two-way interaction between the treatments and storage time were significant. With respect to treatments, the cold water wash gave higher L values than the hot water wash. This may be due to increased enzyme activity at temperatures of 60°C which may have made fruit more susceptible to oxidation. For storage time, a decrease in L value was observed from 0 to 21 days. This suggests that fruit darkened with storage.

Changes in hue angle are shown in Figure 16, and the analysis of variance table is shown below.

Source of Variation	Degrees of Freedom, df	Sum of Squares, SS	Mean Square, MS	F Value	Pr > F (5%)
Treatment, T	2	488.01	244.01	14.13	0.0001
Storage time, S	3	110.77	36.92	2.15	0.10
T x S	6	156.60	26.10	1.52	0.18
Error	100	1720.41	17.20		

Treatments were highly significant, but storage time and the two-way interaction between treatments and storage time were not significant. With respect to treatments, hue angle values of fruit treated with the hot water wash were lower compared to the control and cold water treatment. Hot water may have increased activation of enzymes which may have made fruit more susceptible to darkening.

Changes in firmness are shown in Figure 17. The analysis of variance table is also shown below.

Source of Variation	Degrees of Freedom, df	Sum of Squares, SS	Mean Square, MS	F Value	Pr > F (5%)
Treatment, T	2	1296.08	648.04	3.19	0.05
Storage time, S	3	46766.67	15588.89	76.75	0.0001
T x S	6	1595.01	265.83	1.31	0.26
Error	100	203010.54	203.11		

The results indicated that storage time was highly significant, and fruit firmness increased with storage time. This result may be due to tissue firming at low temperatures, and/or modification of structural components such as lipids in the cuticular wax at low temperatures.

Fruit Microbial Loads

The microbial loads of the control (no washing treatment) and fruit subjected to the cold water (16°C) and hot water (60°C) treatments are shown in Figures 18 and 19. Total aerobic populations, as well as yeast and mold loads, were examined in 1999. Only yeasts and molds were enumerated in 2000. Aerobic populations were not enumerated in 2000, because results from 1999 did not demonstrate consistent significant differences in aerobic counts among the treatments. Analysis of variance results indicated that in 1999 storage day was a significant influence on aerobic and yeast and mold counts, except for the yeast and mold counts of the hot water treatment. In 1999, treatment significantly influenced the yeast and mold counts. In 2000, analysis of variance results revealed that yeast and mold counts. were not significantly influenced by treatment.

In 1999, total aerobic counts generally increased as the storage period progressed (Figure 18). The earlier onset of significantly higher aerobic counts is likely due to the promotion of microbial growth by the increased free-moisture on the washed fruit. Although the fruit were dried by the blower of the washing/drying conveyor unit, it would be expected that some free-moisture would be retained on the fruit. Also, the water adhering to the conveyor which was deposited in the collection container contributed to excess moisture on the fruit. Microbial analysis of the water used revealed that no yeast and mold were present and that the total aerobic counts were negligible.

On any particular storage day, the aerobic populations of the control, cold water wash, and hot water wash samples did not differ from each other significantly. The only exception was

on day 14 when the cold water wash had a significantly higher count than both the other treatments. It is possible that even when considering the added moisture on the washed fruit, the cold water wash was less effective in delaying microbial growth than the hot water wash. Thus, when washing fruit it may be desirable to use a hot water wash to limit aerobic bacterial growth. It should be noted that the hot water wash did not significantly decrease aerobic loads compared to the control. Even though bacterial loads were not significantly lowered, washing of the fruit remains necessary to eliminate soil residues and other contaminates (Nguyen-the and Carlin, 1994).

The most noteable result in 1999 was the significantly lower yeast and mold counts on the hot water wash samples compared to the other treatments. The hot water wash reduced yeast and mold populations by 0.5-0.9 log (Figure 19). However, in 2000 the hot water wash did not reduce yeast and mold populations compared to the other treatments (Figure 20). The differences in these results may have been due to variation in the sample storage methodology and/or to year-to-year variations (i.e. *Entomosporium* was a major disease problem in 1999). The 2000 samples were stored in separate bags of 200 g for each sampling day, and the 1999 samples were stored in bags of 600 g that were sampled over the entire storage period. The volume of fruit stored per bag may have influenced microbial growth conditions. Yet, the initial decrease of yeast and mold counts seen in 1999 on day 0 for the hot water wash was not apparent in 2000 (Figures 19 and 20). It is not clear why the counts were not initially reduced in 2000. Yeast and mold counts were also examined separately in 2000 (Figures 21 and 22). It should be noted that even though the yeast and mold counts were significantly reduced in 1999 by the hot water treatment, reductions greater than 0.5-0.9 log would be desirable. Hot water may improve the efficacy of industrial fruit washing but the reduction in microbial counts may not warrant the input costs of raising the water temperature. Yeast counts on fruit generally range between 2 and 6 log colony forming units/g; molds range between 2 and 4 log colony forming units/g (Dennis, 1987). It appears saskatoon fruit generally have a low surface microbial content based on the fruit sampled in this study.

Conclusions

This project successfully developed a primary processing line suited to the saskatoon fruit industry. The necessity for particular equipment requirements was identified. The equipment must allow for efficient processing. In particular, conveyor speeds throughout the line need to be compatible such that the conveyors can operate in tandem and the line's pace must accommodate manual sorting. The washing equipment should adequately clean the fruit and the subsequent drying step must minimize the amount of moisture adhering to the fruit. It was also found that the amount of moisture adhering to the conveyor belt needs to be removed by the drying equipment so that excess moisture is not collected with the fruit at the end of the line. The equipment design should be such that human handling of the fruit is minimized in order to reduce the risk of contamination. Reducing contamination also requires proper cleaning and sanitizing of the equipment. The equipment construction must facilitate cleaning and sanitation.

The overall quality of the fruit was not compromised by washing and drying. In 1999, the hot water wash was effective in significantly reducing the yeast and mold populations on the surface of the fruit. However, in 2000 the hot water wash did not reduce the yeast and mold populations compared to the other treatments. The differences in these results may have been due

to variation in the sample storage methodology and/or to year-to-year variations (i.e. *Entomosporium* was a major disease problem in 1999). In 1999, 600 g of fruit were stored in one bag and the bag was continually sampled over the storage period. In 2000, 200 g of fruit were stored in one bag and the bag was sampled only once and then disposed of. In general, greater reductions of the microbial populations would have to be evidenced to promote hot water use. In situations were excessive microbial growth is anticipated, such as when counts are initially very high, hot water washing maybe used to extend shelf life. Also, when storage conditions are not ideal, such as temperatures are well above 0°C, even slight reductions in microbial loads may improve shelf life.

Optimum-time temperature combinations for processing were not determined. The equipment limitations, particularly the lack of conveyor speeds available, impeded altering the processing times. Because colder water temperatures were not attainable, the desired range of temperatures were not available. Therefore, determining optimum time-temperature regimes was not possible, given the facilities available.

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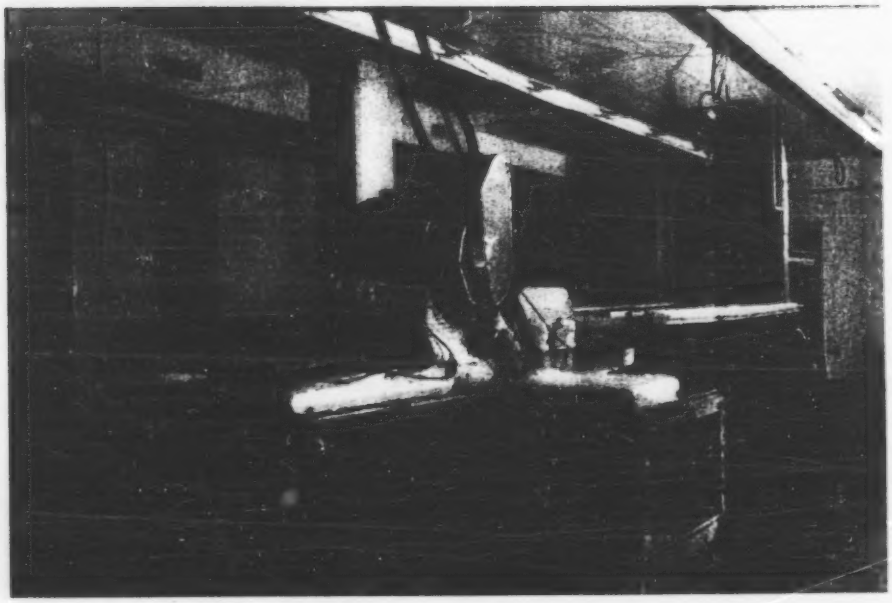
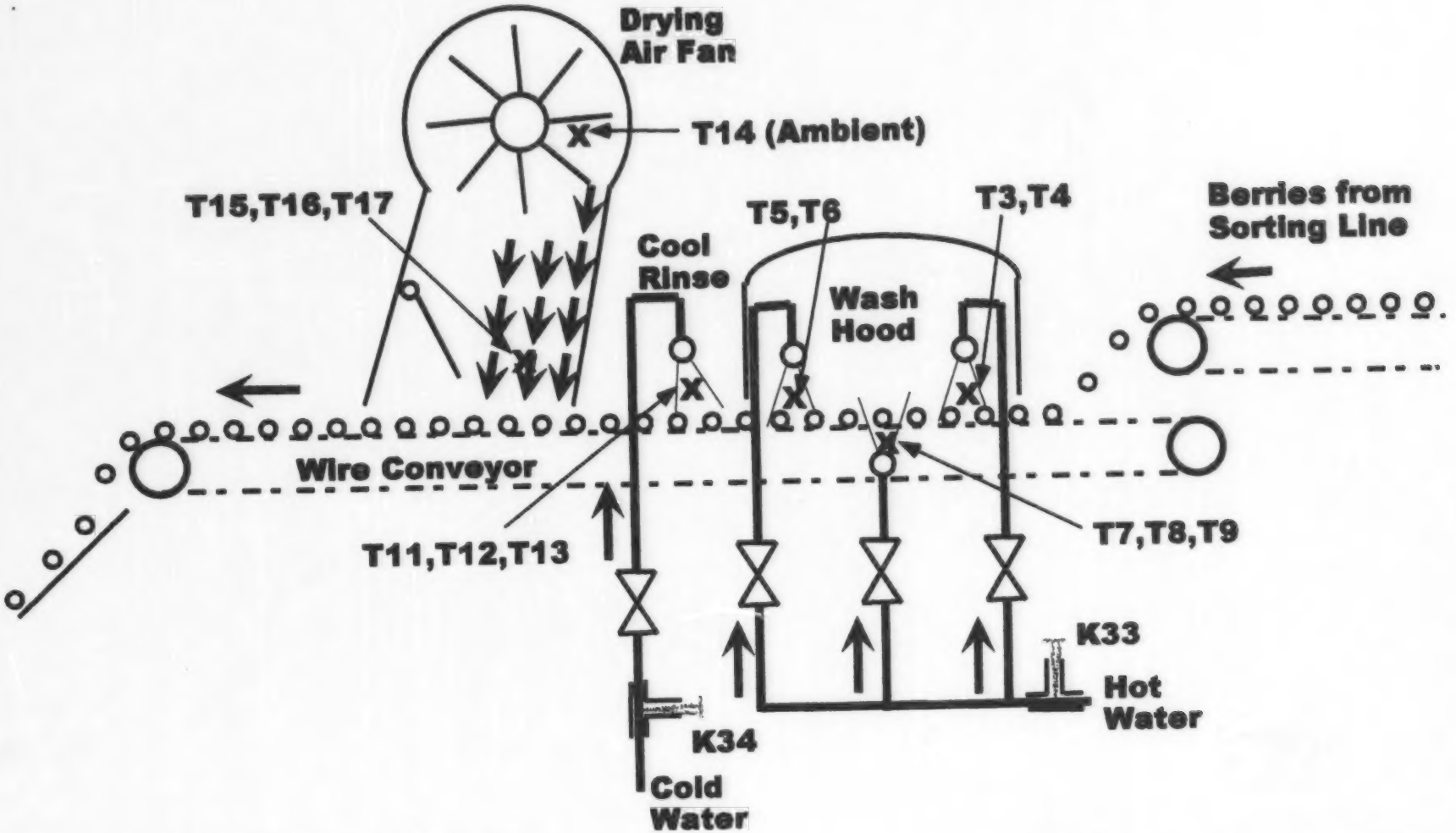


Figure 1. Pilot-scale processing equipment (an air draft cleaner, a sorting table, and a washing/drying conveyor unit) used to clean, sort, wash, and dry saskatoon fruit.

Figure 2. Schematic representation of the locations of thermocouples which monitored water and air temperatures throughout the washing/drying conveyor unit (see following page).



Logger Wireup Diagram

1		2		3	4	5	6	7	8	9	10	11	12	13	14	15
T1		T2		T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15
T18	T19															
16	17															

K33 K34

18 19

Note: T1, T2, T10 - spare T/Cs

BERRY WASH LINE THERMOCOUPLE PLACEMENTS

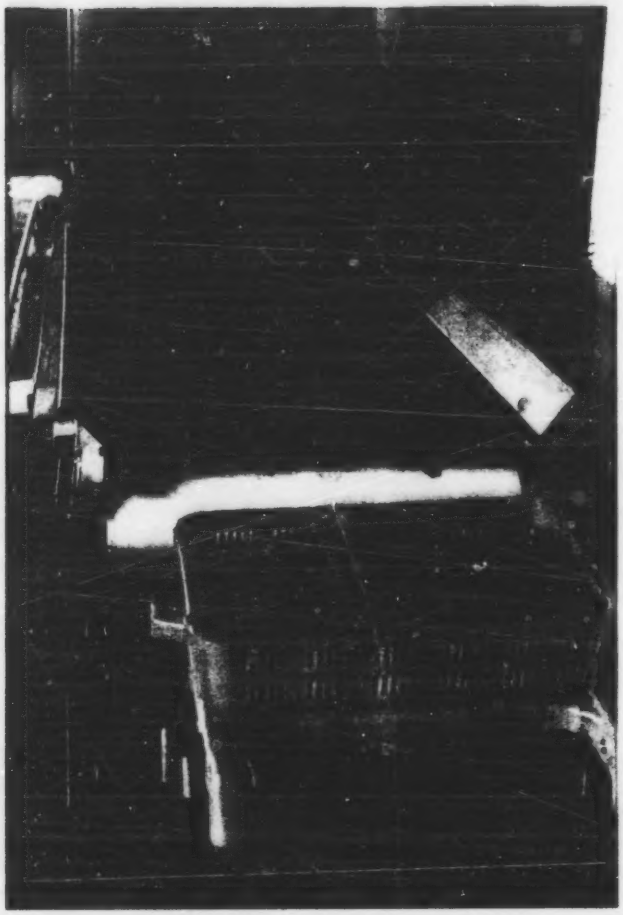


Figure 3. Fruit being deposited on the conveyor of the air draft cleaner (University of Saskatchewan Audio Visual Services, 1999).

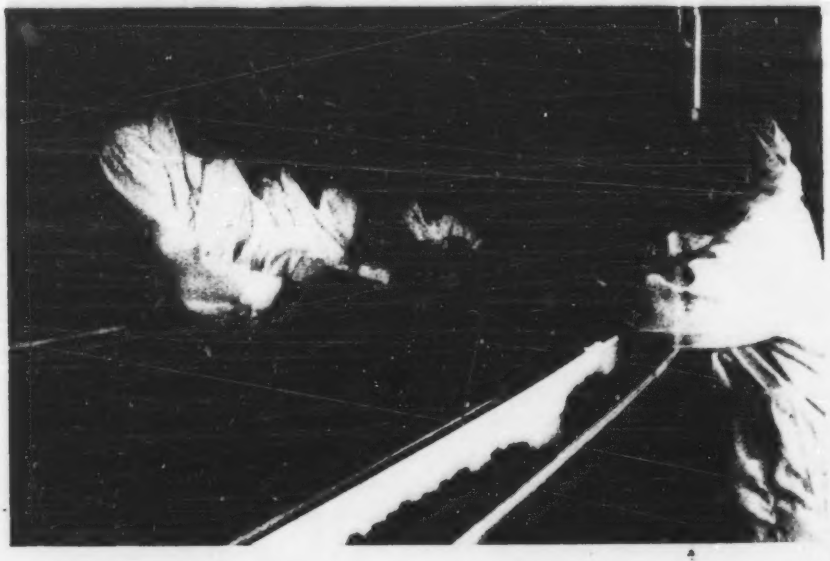


Figure 4. Immature and diseased fruit being manually removed from fruit exiting the air draft cleaner (University of Saskatchewan Audio Visual Services, 1999).

Figure 5. Cleaned fruit being conveyed from the sorting table on to the washing/drying conveyor unit with manual assistance (University of Saskatchewan Audio Visual Services, 1999).

Figure 6. Fruit exiting the blower of the washing/drying conveyor unit (University of Saskatchewan Audio Visual Services, 1999).

Figure 7. Fruit being collected after passing through the spray hood and blower of the washing/drying conveyor unit (University of Saskatchewan Audio Visual Services, 1999)

Table 1. Processing schedule of saskatoon fruit at two different water temperatures.

Day	Rep	Spray Hood Water Temperature (°C)	Cool Rinse Water Temperature (°C)
0	1	16	16
	2	16	16
1	3	16	16
	4	16	16
2	1	60	16
	2	60	16
3	3	60	16
	4	60	16

Table 2. Sampling schedule of saskatoon fruit for quality and microbial testing.

Sampling Days	Sample	Spray Hood Water Temperature (°C)	Cool Rinse Water Temperature (°C)	Quality Analysis[1]	Microbial Analysis[2]
0, 7, 14, 21	Control[3]1a[4]	-	-	✓	✓
	Control 1b	-	-	✓	✓
	Rep 1a	16°C	16°C	✓	✓
	Rep 1b	16°C	16°C	✓	✓
	Control 2a	-	-	✓	✓
	Control 2b	-	-	✓	✓
	Rep 2a	16°C	16°C	✓	✓
	Rep 2b	16°C	16°C		
1, 8, 15, 22	Control 3a	-	-	✓	✓
	Control 3b	-	-	✓	✓
	Rep 3a	16°C	16°C	✓	✓
	Rep 3b	16°C	16°C	✓	✓
	Control 4a	-	-	✓	✓
	Control 4b	-	-	✓	✓
	Rep 4a	16°C	16°C	✓	✓
	Rep 4b	16°C	16°C		
2, 9, 16, 23	Control 1a	-	-	✓	✓
	Control 1b	-	-	✓	✓
	Rep 1a	60°C	16°C	✓	✓
	Rep 1b	60°C	16°C	✓	✓
	Control 2a	-	-	✓	✓
	Control 2b	-	-	✓	✓
	Rep 2a	60°C	16°C	✓	✓
	Rep 2b	60°C	16°C		
3, 10, 17, 24	Control 3a	-	-	✓	✓
	Control 3b	-	-	✓	✓
	Rep 3a	60°C	16°C	✓	✓
	Rep 3b	60°C	16°C	✓	✓
	Control 4a	-	-	✓	✓
	Control 4b	-	-	✓	✓
	Rep 4a	60°C	16°C	✓	✓
	Rep 4b	60°C	16°C		

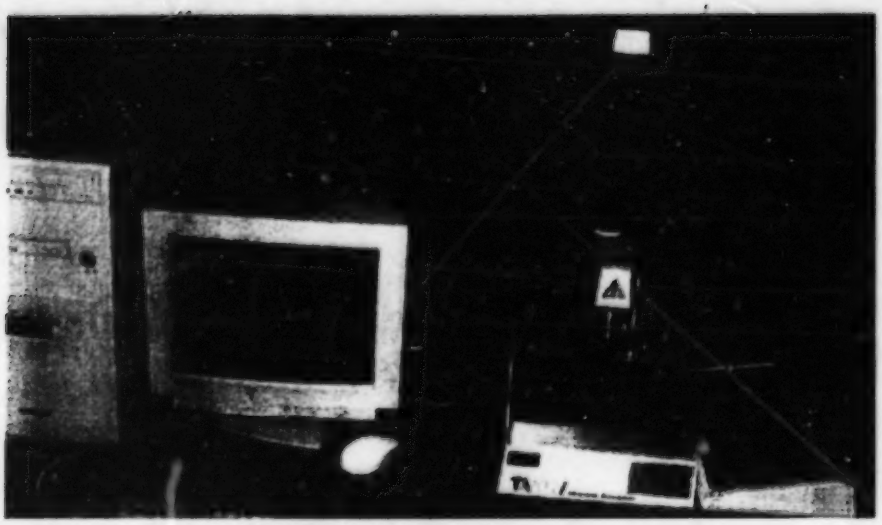
[1]Fruit quality was analyzed in 1999 only.
[2] Aerobic and yeast and mold populations were enumerated in 1999. In 2000, only yeast and mold populations were counted.
[3] Control refers to a sample taken after manual sorting but prior to the fruits' entry into the washing/drying conveyor unit.
[4] Letter denotes a duplicate subsample.

(a)

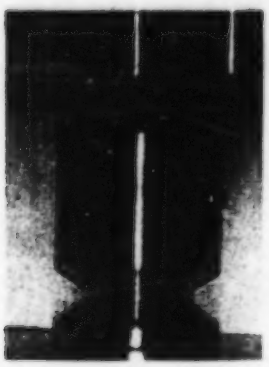
(b)

(c)

Figure 8. Pilot scale processing equipment being cleaned and sanitized. (a) Cleaning the sorting table; (b) Cleaning the washing/drying conveyor unit; (c) Sanitizing the washing/drying conveyor unit (University of Saskatchewan Audio Visual Services, 1999).



(a)



(b)

Figure 9. Equipment used to analyze saskatoon fruit texture. (a) The TA.XT2 texture analyzer (Texture Technologies Corp., Scarsdale, NY); (b) Ten fruit being compressed with a 10 cm diameter compression plate.

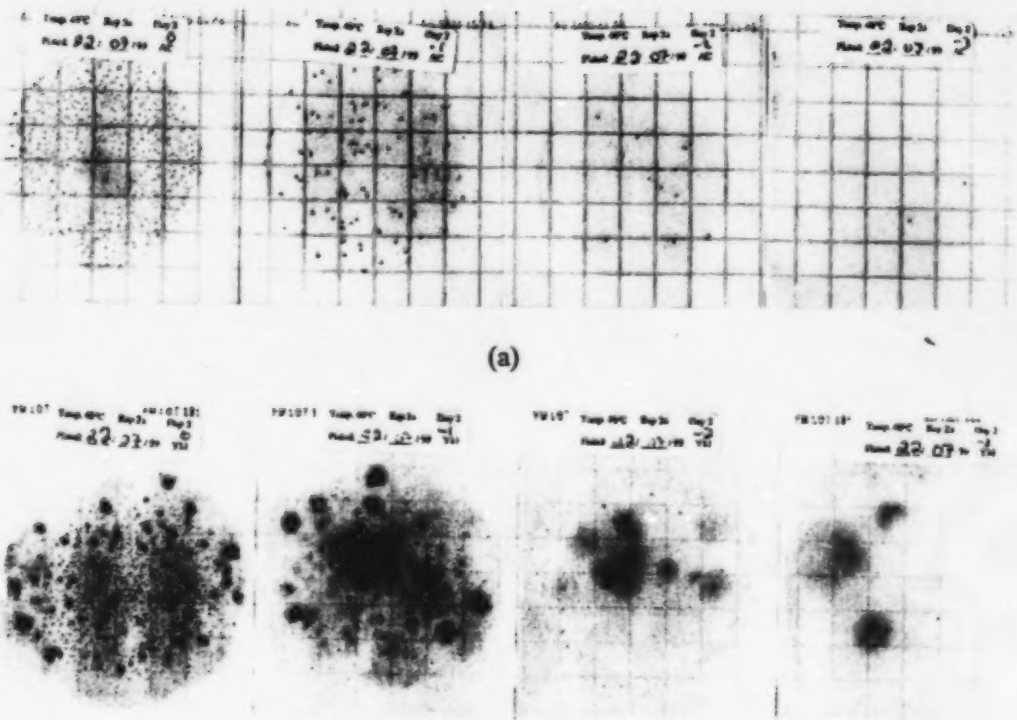


Figure 10. Examples of sample rinses plated for microbial enumeration subsequent to incubation. (a) Aerobic plate counts (dilutions 10^{-1} to 10^{-5} from left to right); (b) Yeast and mold counts (dilutions 10^{-1} to 10^{-5} from left to right).

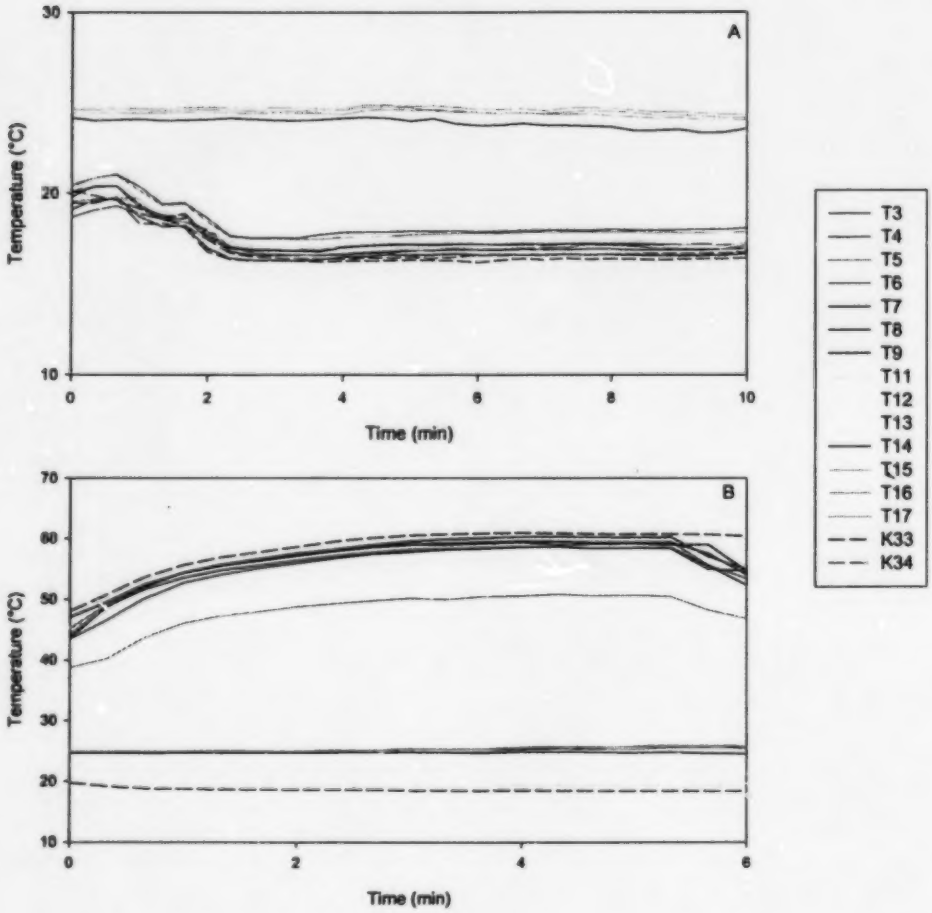


Figure 11. Temperature profiles from 1999 of the water dispensed by the cool rinse spray bar (T11, T12, T13) and the wash hood spray bars (T3, T4, T5, T6,T7, T8, T9) of the washing/drying conveyor unit; also of the water entering the the cool rinse (T34) and the wash hood (K33) spray bars. (Refer to Figure 2 to identify the location of other thermocouples.) (A) Cold water wash where the cool rinse and wash hood spray bars dispensed 16°C water. (B) Hot water wash where the cool rinse spray bar dispensed 16°C water and the wash hood spray bars dispensed 60°C water.

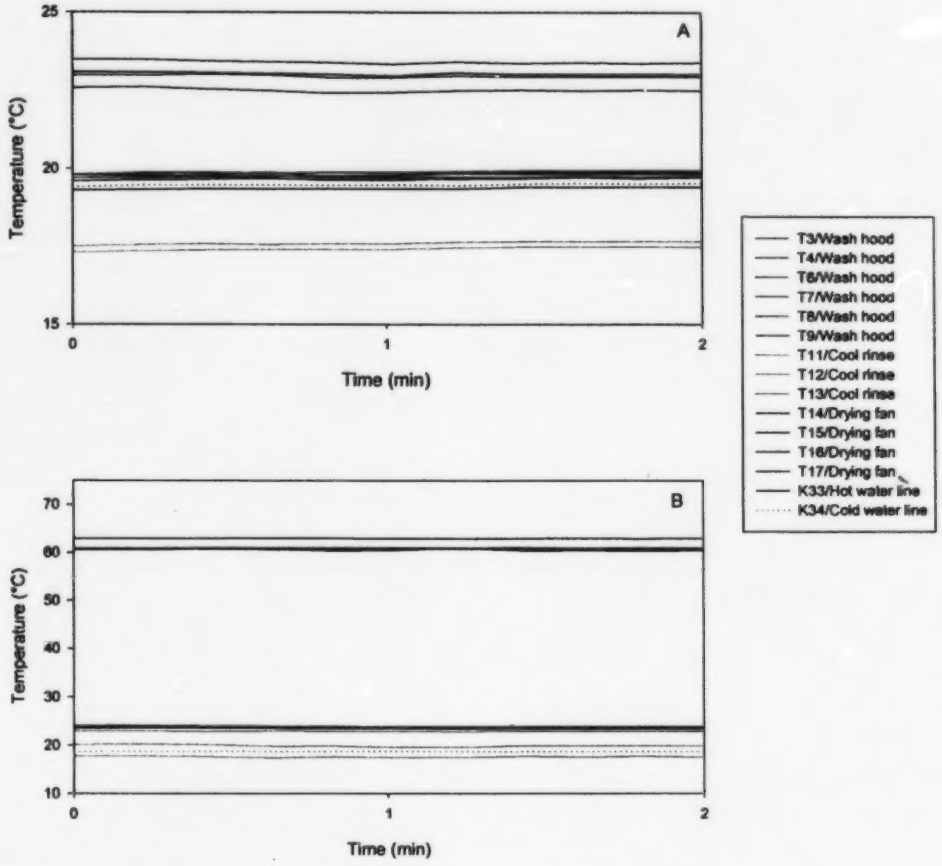


Figure 12. Temperature profiles from 1999 of the water dispensed by the cool rinse spray bar (T11, T12, T13) and the wash hood spray bars (T3, T4, T5, T6,T7, T8, T9) of the washing/drying conveyor unit; also of the water entering the the cool rinse (T34) and the wash hood (K33) spray bars. (Refer to Figure 2 to identify the location of other thermocouples.) (A) Cold water wash where the cool rinse and wash hood spray bars dispensed 19°C water. (B) Hot water wash where the cool rinse spray bar dispensed 19°C water and the wash hood spray bars dispensed 60°C water.

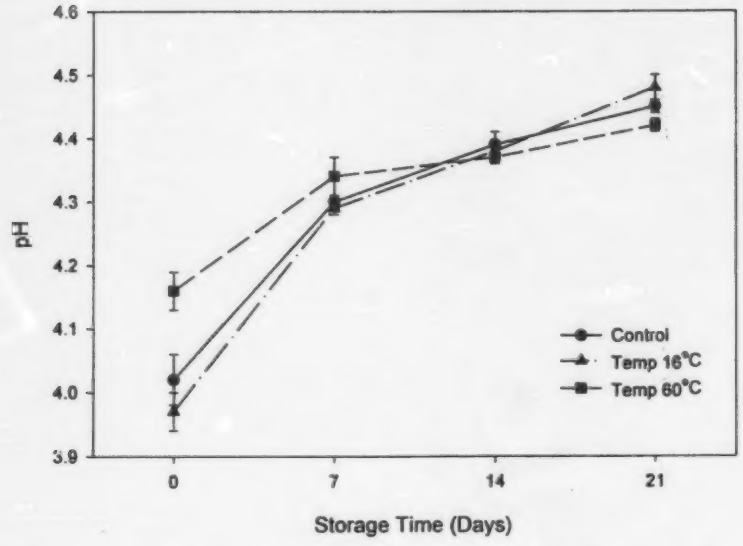


Figure 13. The pHs of the control, cold water wash treatment (16°C), and hot water wash treatment (60°C) samples over the storage period.

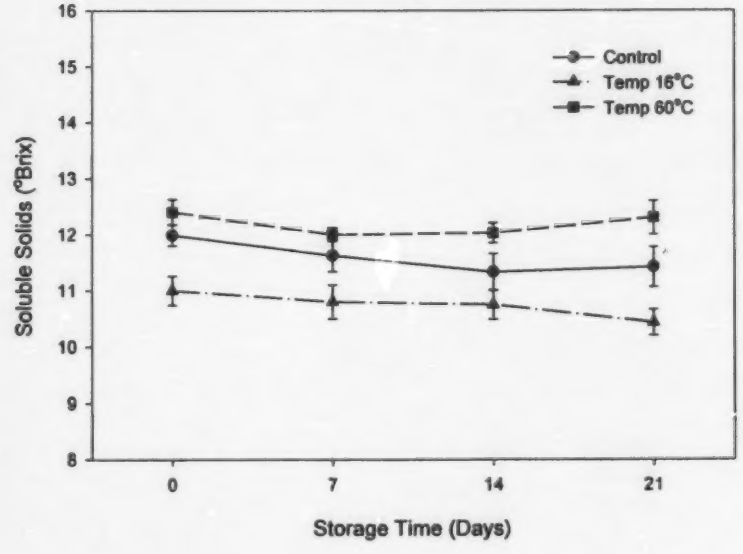


Figure 14. The soluble solids contents of the control, cold water wash treatment (16°C), and hot water wash treatment (60°C) samples over the storage period.

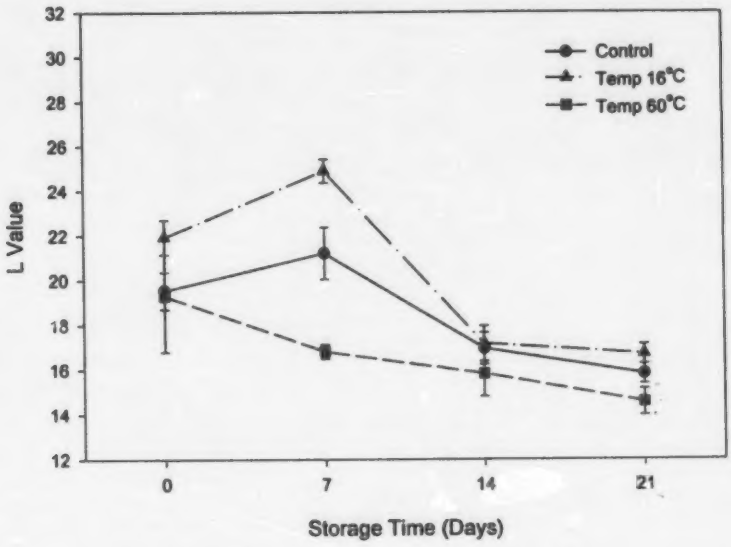


Figure 15. The L values of the control, cold water wash treatment (16°C), and hot water wash treatment (60°C) samples over the storage period.

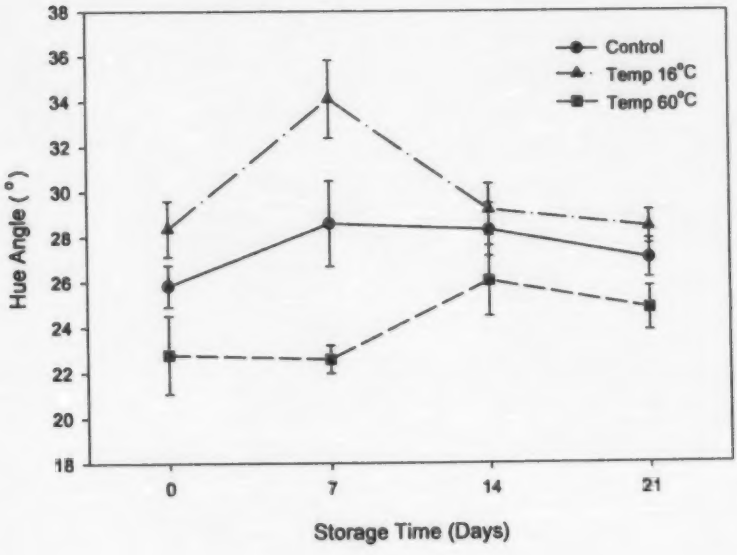


Figure 16. The hue angles of the control, cold water wash treatment (16°C), and hot water wash treatment (60°C) samples over the storage period.

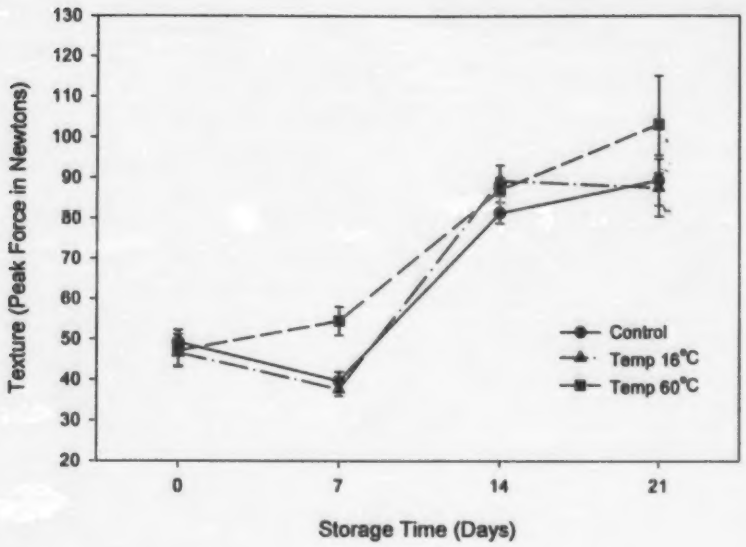


Figure 17. The texture values of the control, cold water wash treatment (16°C), and hot water wash treatment (60°C) samples over the storage period in 1999.

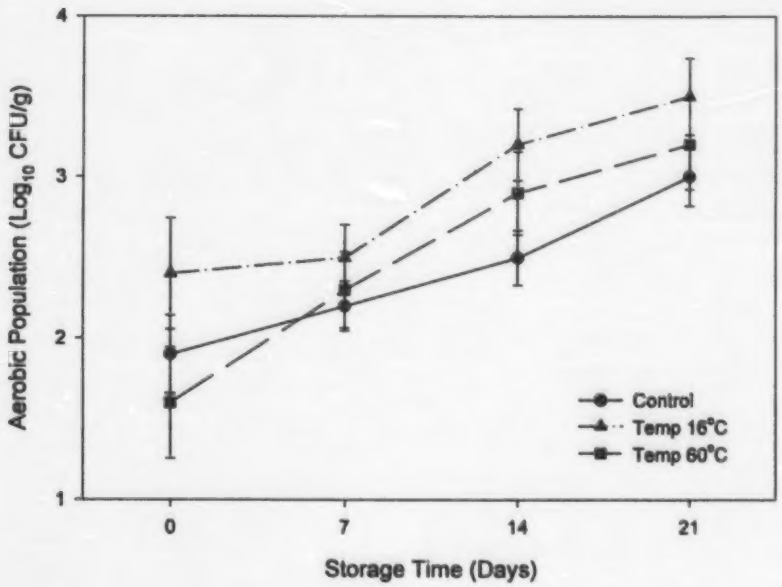


Figure 18. Populations of total aerobic microorganisms on the surface of control, cold water wash (16°C), and hot water wash (60°C) samples over the storage period in 1999.

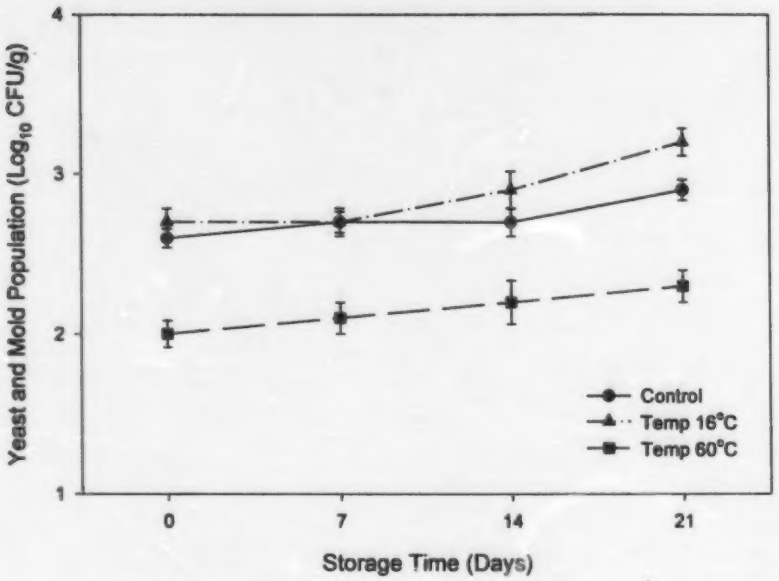


Figure 19. Populations of yeasts and molds on the surface of control, cold water wash (16°C), and hot water wash (60°C) samples over the storage period in 1999.

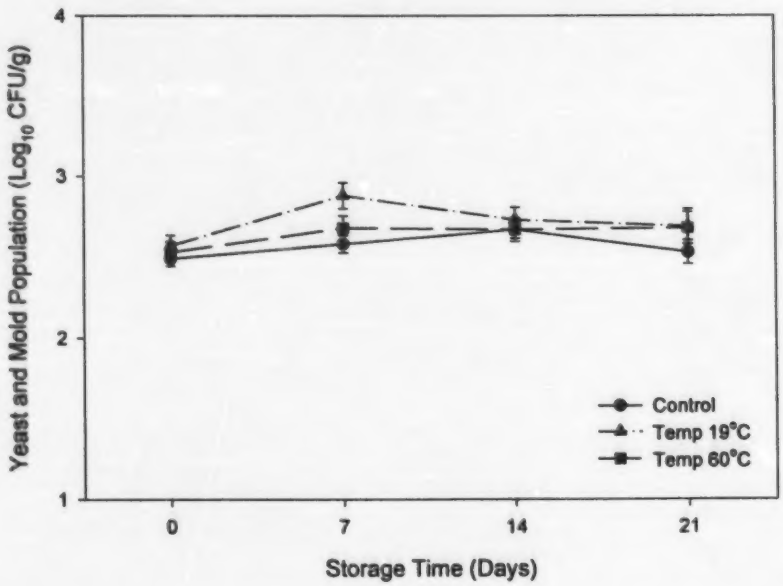


Figure 20. Populations of yeasts and molds on the surface of control, cold water wash (19°C), and hot water wash (60°C) samples over the storage period in 2000.

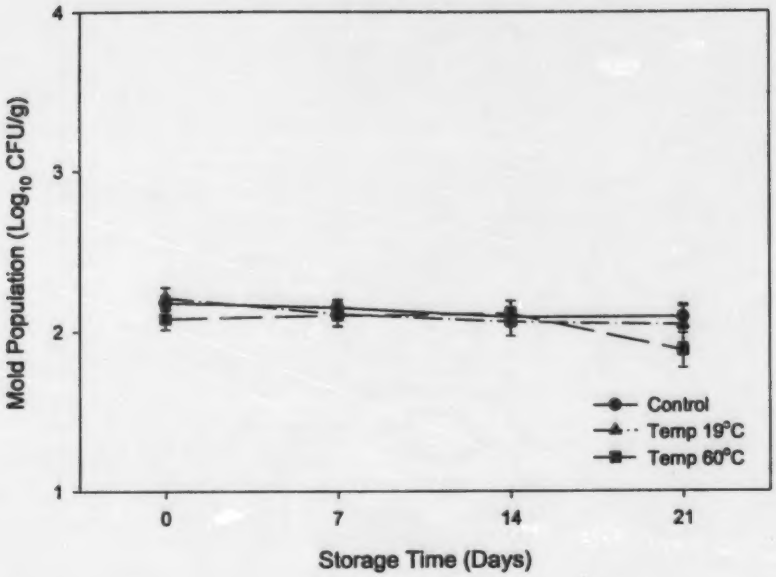


Figure 21. Populations of molds on the surface of control, cold water wash (19°C), and hot water wash (60°C) samples over the storage period in 2000.

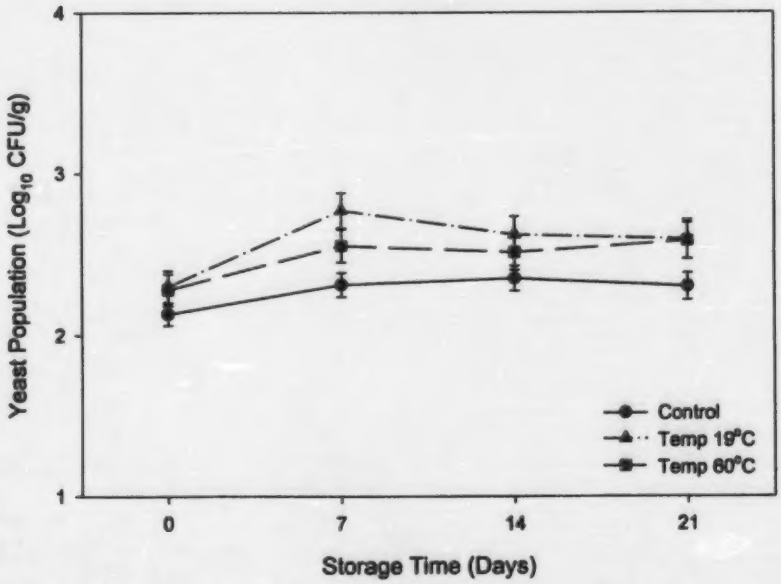


Figure 22. Populations of yeasts on the surface of control, cold water wash (19°C), and hot water wash (60°C) samples over the storage period in 2000.

4) Indications For Further Development

Further developments in the area of primary processing of saskatoon fruit may include adding compounds to the wash water which would aid in decontaminating the fruit and extending its shelf life. Commercial fruit and vegetable processors often add chlorine to wash water, and more recently alternatives such as ozone and acetic acid have been used. Further developments also include equipment improvements such as variable speed conveyors throughout the processing line and conveyors of compatible widths. As well, improvements to assist removing moisture from the conveyors are needed. The possibility exists to inoculate fruit samples with microbes to further examine the effect of washing temperatures on microbial populations. Also, determining optimum time-temperature combinations for processing given equipment improvements may be appropriate.

5) Information Sharing

Seventeen growers toured the primary processing line established at the Food Centre (Saskatoon, SK) on July 26, 1999. Information from this project was presented to growers and other industry stakeholders at the Growers Helping Growers conference (November 24-25, 2000, Saskatoon, SK) sponsored by the Saskatchewan Fruit Growers Association, University of Saskatchewan, and Saskatchewan Agriculture and Food. A video showing a primary processing line for saskatoon fruit is included in this report and will be distributed to the Saskatchewan Fruit Growers Association, the Food Centre, Pattison BNE (equipment manufacturer), and other interested parties.

6) Success & Relationship to Objectives

The project has met objectives (1) to develop a pilot-scale operation for washing and drying of fresh saskatoon fruit in accordance with recommended food safety guidelines for fresh produce processing and (2) to examine the effects of hot and cold water washing treatments followed by drying on the shelf-life of fresh saskatoon fruit. The third objective, to determine the optimum time-temperature combinations for the wash/dry unit for fresh-pack saskatoon fruit, was not met due to equipment limitations and the lack of consistent results. The ability to control time and temperature were limited by the range of conveyor speeds and water temperatures attainable. The decrease in yeast and mold populations evidenced in 1999 with the hot water wash was not apparent in 2000. Therefore, there was not a basis for determining optimum time-temperature combinations in relation to reducing microbial load reduction.

7) Outputs & Deliverables

The project has been completed. Project outputs have included:

1) Assembly of a demonstration pilot-scale operation for washing and drying of fresh saskatoon fruit.

2) Obtaining information on the effects of hot and cold water washing treatments on the shelf-life of fresh Saskatoon fruit.

3) Distribution of the information derived from outputs 1 & 2 to industry and academia via presentations at technical meetings.

C) Personnel

R. St-Pierre - 5%
W. Ziehl - 20%
S. Agblor -15%
W. Pomedli -15%
L. Michels - 100%
C. Bulogosi -100%
S. Varde -100%

D) Equipment

None >$1000 purchased. Rented: Air draft cleaner, sorting table, and washing/drying unit.

E) Project Photos

Refer to Technical Report.

F) Innovation Fund Acknowledgement

The Fund was acknowledged when growers toured the primary processing line at the Food Centre (Saskatoon, SK) on July 26, 1999. The Fund was also acknowledged at the Growers Helping Growers conference (November 24-25, 2000, Saskatoon, SK) where project information was presented. The video produced as part of this report acknowledges support from the Innovation Fund.

G) Copies of Information Developed

A video has been included with the report.

H) Expense Statement

Sent under separate cover by Research Accounts, University of Saskatchewan.